APPENDIX A - ELEMENTS OF RESEARCH PLAN FOR WEST COAST GROUNDFISH

I. Status of Stocks

The goal of research on status of stocks is to determine the health (status) of harvested stocks, and to forecast the potential fishery yield from a long-term harvest policy. Harvest recommendations involve balancing a sufficiently high harvest rate that will approach maximum sustainable yield against the possibility of overfishing and causing a depletion of the resource or other harm to the ecosystem. The Sustainable Fisheries Act requires that a precautionary approach be taken to harvest management in the face of uncertainty on stock productivity, and the SFA established formal requirements to identify overfished stocks and to establish rebuilding plans for these depleted stocks. Further, for species that exhibit extreme levels of depletion, the Endangered Species Act established a process for determining if there is a threat of extinction for any distinct population segment of the species.

A. Life history and stock distribution

1. Objective: Provide biological data for accurate stock assessments and other fishery evaluations. This includes basic biological information such as stock structure, age composition, growth, and reproduction.
2. Current Program
   a. Stock distribution and movement information for egg, larval, juvenile, and adult life stages is determined from plankton surveys, fishery resource assessment surveys, fishery logbooks, and tagging studies.
   b. Genetic characteristics and species' population structure has been investigated for a few major groundfish species using mapping, genetics, morphology, parasites, microconstituents and other methods.
   c. Age, growth, maturation
      (1) "Production ageing" of fishery and survey specimens for major species in order to determine patterns in recruitment and enable age-based assessment methods.
      (2) Validation of ageing methods via radiometric, tag-recapture, other techniques.
      (3) CARE (US-Canada committee of age reading experts) provides interagency quality assurance on age determinations.
      (4) Where a good time series of age data exist, track changes in size-at-age (growth) potentially related to environmental or density-dependent factors.
3. Areas of Improvement
   a. Collect data on age-specific growth and reproduction (maturity and fecundity) for more species.
   b. Investigate new methods to estimate natural mortality rates.
   c. Extend genetic examination of stock structure to more species that have a high probability of having separate distinct populations
   d. Improve validation and precision of ageing methods.
   e. Describe degree of mixing between and within populations using genetic, tagging, and other methods.
   f. Investigate temporal and spatial trends in growth and maturation, and impact on assessments.
   g. Expand life-history data collection to include additional measures of fish health and

fitness (e.g., disease, parasite loads, bioenergetic indicators such as lipid and protein content).

h. Create an efficient access to information from all life history research projects, which are distributed among many agencies and academic institutions. This could include a centralized repository for summary information (website), a grant dedicated to academic studies of life history, and other approaches.

B. Fishery catch information

1. Objective: Document total fishery catch so that stock assessment models can correctly separate fishing from natural causes of changes in fish abundance, and so that the effectiveness of current regulations can be determined. A complete program should provide on an ongoing basis:
   a. Timely estimates of total commercial and recreational catch for each species by each gear, location, and time stratum.
   b. Information on bycatch and discards.
   c. Biological characteristics (age and size composition) of the catch.
   d. Standardized measurement of fishing effort and catch-per-effort to complement fishery-independent resource survey data.
   e. Geographic distribution of catch and effort.
   f. Costs and other economic attributes of fishing and processing activities.

2. Current Program
   a. Landed commercial catch is monitored shoreside by the states and PSMFC with partial funding through the PacFIN grant, and coastwide data access through PacFIN data system. Basic program is based upon comprehensive mandatory commercial landing receipts to determine landed catch, and biological samples by port biologists to determine species composition of each market category, and to collect size and age data.
   b. The growing nearshore commercial groundfish fisheries, including the live rockfish fishery, are monitored by state programs, but the effectiveness of conventional fishery monitoring programs for this highly distributed fishery are in need of review. Washington has major efforts directed towards nearshore fisheries for lingcod and black rockfish.
   c. Recreational fishery catch is estimated from interviews and other statistical sampling methods. There are state programs and the federal Marine Recreational Fisheries Statistics (MRFSS) program.
   d. The catch made by or delivered to the at-sea whiting processors is monitored by the North Pacific observer program administered through the Alaska Fisheries Science Center (AFSC).
   e. Logbooks
      (1) Trawl logbooks - coastwide trawl logbook program collects tow by tow data on trawl fishing effort and retained catch. Data from the three state programs are now mirrored into PacFIN. Statistical analyses to standardize fishing effort over time and between vessels have been conducted by NMFS and academic researchers.
      (2) Commercial Passenger Fishing Vessels (head boats) have a logbook program

in California that has been used in some stock assessments.
(3) Logbooks exist for some nontrawl commercial gears in some states, but no computerized database or concerted effort at standardization or compliance.

f. Observer program
(1) At-sea program (observers) for the whiting midwater trawl fishery is administered by the AFSC. This program provides information on total whiting catch, bycatch of other species, and biological samples of whiting to determine age composition of catch for use in stock assessment models.
(2) Pilot trawl observer program conducted primarily off Oregon in 1985-87 and 1996-98. Data from earlier study have been extrapolated and are basis of most current discard estimates. Data from later study are being analyzed.

3. Areas of Improvement
a. Review port sampling priorities to provide most efficient use of samplers, and to define the potential gains from addition of more samplers.
b. Improve accuracy of recreational catch data by reviewing statistical design and implementation of MRFSS on West Coast. Seek cost-effective ways to reduce potential bias and improve precision of estimates of recreational catch.
c. Improve timeliness, accuracy, and integration of port sampling, fish tickets, logbooks, and observer data by deploying an electronic logbook within a comprehensively integrated data system.
d. Determine accurate information on total catch by deploying an at-sea observer program. There is a need to determine discard of marketable groundfish caused by trip limits and to determine the bycatch of prohibited species (salmon, halibut).
e. Obtain more complete information on patterns of fishing activity and catch by developing a logbook program for nontrawl gears, including adequate outreach to assure good compliance and accuracy.
f. Investigate alternative methods to obtain catch data from small-scale, highly distributed nearshore fisheries (e.g. live rockfish fishery).

C. Population abundance monitoring
1. Objective: Measure trends in abundance for groundfish species. Normally a resource survey is implemented as a long-term, ongoing index to track natural and anthropogenic changes in fish abundance. In some cases, a single survey or a short time series can be directly calibrated to absolute abundance. An annual survey will most closely track natural biological fluctuations and smooth out apparent fluctuations caused by environmental effects on catchability.

2. Current Program
a. Midwater - (Pacific whiting) acoustic and midwater trawl survey conducted triennially (1977-1998) with sufficient coastwise coverage using FRV *Miller Freeman*. Recent surveys have been coordinated with Canadian acoustic survey to assure adequate coverage in northern areas.
b. Shelf groundfish - bottom trawl survey conducted triennially (1977-1998) in midsummer, sufficient coastwise coverage for most target species but does not cover south of Point Conception; survey covers the 30-275 fathoms range of

bottom depths using two large (125 foot) chartered vessels.
(1) also serves as triennial recruitment index for age 1 sablefish and whiting.
(2) incidental catch of nearshore flatfish serves as index of abundance for some of these species, but trawl footrope is not optimal for these species.

c. Slope species (sablefish, dover sole, thornyheads) - bottom trawl survey conducted near annual in mid-autumn, covers 100-700 fathom range of bottom depth using the FRV *Miller Freeman*. Available days at sea have not been sufficient to achieve desired level of coverage. A pilot slope bottom trawl survey was started in 1998 and 1999. It covers same geographic and depth range as the FRV survey, but is done in summer from four medium-sized (65-85 foot) chartered vessels.
d. Nearshore rockfish
(1) SCUBA and hook&line surveys for various nearshore rockfish off California by California Department of Fish and Game (CDFG).
(2) mark-recapture survey for black rockfish and lingcod by Washington Department of Fish and Wildlife (WDFW).
e. Shelf rockfish recruitment - midwater trawl survey off Central California from FRV by Southwest Fisheries Science Center (SWFSC)-Tiburon for age 0 rockfish.
f. Multi-species - multi-disciplinary oceanographic and egg and larvae survey off southern California (California Cooperative Oceanographic Fisheries Investigation (CalCOFI)). Currently is conducted quarterly using National Oceanic and Atmospheric Administration (NOAA) and University-National Oceanographic Laboratory System (UNOLS) vessels. May provide an index of spawning biomass for species that have a significant portion of their spawning in this area.

3. Areas of Improvement
a. Develop and implement a survey method for each of the groundfish assemblages, and for each region of the coast. Particular needs are for all groundfish south of Point Conception, for nearshore flatfish, and for untrawlable habitats coastwide.
b. Standard bottom trawl survey - Consider merits of combining the three current bottom trawl surveys (which differ in gear, vessel size, season, depth range, target species) into one or two surveys that will cover nearshore flatfish, shelf rockfish, and deep slope species.
c. Determine potential improvement in survey accuracy by stratifying survey effort on finer habitat features.
d. Evaluate alternative survey methodologies including egg and larval, mark-recapture, hook and line, visual. Particular need is to develop methods to apply in untrawlable habitats.
e. Improve tracking of natural fluctuations in Pacific whiting abundance and US-Canada distribution by increasing frequency of whiting acoustic survey that currently is only triennial.
f. Improve time series data on recruitment of groundfish species:
(1) Evaluate merits of recruitment (i.e., young fish) information that could be obtained from an annual standard bottom trawl survey. In particular for sablefish, whiting, and rockfish species.
(2) Evaluate merits of midwater trawl surveys to provide an index of recruitment for age 0 rockfish and whiting. Consider expanding the rockfish recruitment survey that is currently conducted only off central California and consider

results of pilot studies by the Pacific Whiting Conservation Cooperative.

g. Determine relative value of alternative indexes of abundance, especially off southern California where sanitation district trawl surveys, power plant impingement data, and egg and larval surveys may have useful information for some groundfish.
h. Direct calibration of surveys.
   (1) Target strength measurements for whiting.
   (2) Direct observation of fish density using visual&laser methods.
   (3) Investigate catchability characteristics of sampling methods, in particular fish behavior in response to sampling gear, and environmental effects on fish-gear interactions.
   (4) Mark-recapture methods.

D. Stock assessment
   1. Objective: Determine the status of each groundfish species. The primary goals are identifying overfished and threatened stocks, guiding and monitoring rebuilding of these stocks, and forecasting biologically sustainable harvest levels for healthy stocks. For species that exhibit extreme levels of depletion, determine whether there is a risk of extinction for any distinct population segment of the species.
   2. Current program
      a. Where there are sufficient data, stock assessments are conducted by using the life history data to build a biologically realistic model of the fish stock, and calibrating this model so that it reproduces the observed fishery and survey data as closely as possible. During the 1990s, most West Coast groundfish assessments were conducted using the stock synthesis model. Recently there has been development of similar, but more powerful, models using state-of-the-art software tools.
      b. Approximately six assessments are conducted each year; 26 species have been assessed (with varying degrees of precision). Several species are assessed approximately every three to four years, some have been assessed only once, and only Pacific whiting is examined annually.
      c. Assessments are conducted by scientists at the NWFSC, AKFSC, SWFSC, WDFW, ODFW, CDFW, Oregon State University, and University of Washington.
      d. Approximately three STAR review panels each review approximately two assessments in week-long review sessions open to the public.
      e. Assessment schedule and review process is coordinated by the NMFS Stock Assessment Coordinator in conjunction with the PFMC's Scientific and Statistical Committee.
      f. Assessments and reviews are transmitted to the PFMC for use in determining acceptable biological catch for the assessed species.
      g. Many species have never been assessed and lack the data necessary to conduct even a qualitative assessment (i.e., is trend up, down or stable?). The OY (optimum yield) for these "other rockfish" was recently reduced to 50% of historical catch in order to take a more precautionary approach to this lack of information. The OY for rockfish with less rigorous assessments were reduced to 75% of the estimated ABC (allowable biological catch).
   3. Areas of Improvement

a. Develop models to better quantify uncertainty and aid. communication/ implementation of precautionary approach.
b. Develop models to specifically aid in the assessment of species with limited data.
c. Improve standardization of assessment methods and conduct a formal review of these methods so that the subsequent review of each species' assessment can be shortened. This could allow more assessments to be reviewed each year.
d. Develop models to better represent spatially-structured populations, e.g., populations with low rates of internal mixing or populations with ontogenetic patterns spanning a range of habitats.
e. Develop a concise summary of the status of information for each groundfish species, even those that lack quantitative assessment data. Goal is to steer priorities to filling key gaps, and providing minimal information for precautionary management of each species. The results could be disseminated on an ongoing basis as a web-based information center with links to government databases and academic research projects.

E. Rebuilding plans
1. Objective - Rebuild depleted (e.g., overfished) stocks to levels that can support maximum sustainable yield within a specified time frame. Also see Management Support below.
2. Current program -
   a. determine expected effect of reduced fishery harvest on expected time frame for rebuilding to target level under prevailing environmental conditions and recruitment levels.
3. Areas of improvement
   a. Incorporate increased knowledge of cycles in ocean climate on the rebuilding target and the expected time frame to recovery
   b. Improve methods of characterizing uncertainty in analyzing alternative rebuilding strategies, and future biological and economic risks associated with alternatives.
   c. Determine and mitigate effect of degraded habitat on recovery.
   d. Evaluate artificial propagation methods to accelerate recovery, supplement depleted stocks, and increase production of valuable fishery products.

F. Stakeholder involvement
1. Objective - Improve design of data collection programs, correctly interpret currently available data, and develop means for stakeholders to invest in knowledge that will increase certainty that current harvest levels are safe and may allow higher harvest levels that are equally safe. Develop fair and equitable protocols to enable stakeholders to partner with NMFS to obtain scientifically valid information.
2. Potential mechanisms include:
   a. Better interpretation of fishery logbook data and other fishery data through good scientist-fisherman dialogue.
   b. Tracking changes in fish distribution and fishing effort through increased use of fishery logbook programs.
   c. Expanded collection of biological samples and environmental data through direct involvement of fishermen.

d. Increased precision of resource surveys by increasing sample size with chartered fishing vessels. High cost-effectiveness if allocation of fishing rights can be used to compensate participating vessels.
e. Other

II. Socioeconomic Issues

Goal - Guide development of management actions that have fair and equitable impacts across all fishery stakeholders, and that obtain the greatest benefits from use of living marine resources, including commercial harvest, recreational opportunities, nonconsumptive uses, and aquaculture.

A. Current Program
   1. Analysis of potential economic effects of proposed fishery management actions.
   2. Analysis of allocation among user groups.
   3. Regulatory Flexibility Analyses and other mandated analyses for management actions.

B. Areas of Improvement
   1. Improved understanding of the net economic value and income impacts generated by commercial and recreational fishing opportunities.
   2. Improved benefit-cost analysis of management alternatives. A short-term need is evaluation of the benefits associated with the current vessel catch limit system used to achieve year-round fishing opportunities at the cost of induced discard.
   3. Bio-economic analysis of long-term harvest policies.
   4. Analysis of impact on fishing communities.
   5. More complete Regulatory Flexibility Analyses for management actions.
   6. Systems for market-based allocation of access to harvest rights.

III. Manmade Stress on Groundfish and their Essential Habitat

Goal - To identify, understand and seek means to reduce potential risks to fish stocks, their essential habitat, or other components of the ecosystem. Such investigations have a strong role in developing our ability to evaluate impacts on Essential Fish Habitat. These anthropogenic risks include all factors other than the direct effect of fishery catch, which is studied under the Status of Stocks topic. There will be significant interaction between study of these stress factors and the Ecosystem topic, which will include description of ecosystem functions and dependence of the ecosystem function on habitat. In addition to identifying risks, these studies will also seek to develop methods to reduce adverse impacts.

A. Gear impacts on habitat
   1. Objective - Minimize, to the extent practicable, the negative impact of fishing gears on the marine habitat and biota, especially those habitats and prey species determined to be of particular importance to the productivity of groundfish.
   2. Current Program
      a. Comparative studies of marine benthic habitat and biota characteristics in heavily versus lightly trawled habitats are being conducted off central California.
   3. Areas for Improvement
      a. Determine extent and magnitude of impacts of all fishing gears on marine benthic habitat and biota. Consider using well-monitored research reserves to conduct such studies.
      b. Develop modified fishing gears and deployment methods that reduce adverse impacts of gear on the habitat.

B. Bycatch and discarded catch
   1. Objective - Reduce impact of fisheries on nonretained, nontarget species (bycatch); accurately account for the total mortality attributable to fisheries, and reduce wastage associated with discard of potentially marketable fish products.
   2. Current program
      a. Rough estimates of the levels of discard for major groundfish species, halibut and salmon have been made, primarily on the basis of limited trawl observer programs.
      b. Some knowledge of the factors affecting mortality of discarded halibut and sablefish have been obtained from field and laboratory studies.
      c. Some knowledge of the size/age selectivity of fishing gear (especially trawl) through past directed studies and ongoing examination of the size/age composition of landed catch.
   3. Areas for Improvement
      a. Improve knowledge of total fishery mortality by initiating more comprehensive observer programs.
      b. Improve knowledge of nonretained fishing mortality by conducting research on the mortality of discarded bycatch, and the mortality of fish that encounter fishing gear but are not taken.
      c. Evaluate technical means to reduce discard by improving selectivity of fishing gears and improving ability to forecast times and areas where bycatch will be lower.
      d. Develop methods for fuller utilization of current discards.
      e. Evaluate benefits and costs of technical discard reduction and utilization methods

and possible socioeconomic incentives/ disincentives to discard reduction.

C. Impact of disease, contaminants, exotic species and other factors on fish health and productivity
   1. Objective: provide quantitative linkage between contaminant exposure and factors related to fish health and productivity that can be incorporated into stock assessments.
   2. Current Program - Substantial data available on tissue contaminant concentrations for a few groundfish species at selected locations, but little or no information for others. Linkage between contaminant exposure and productivity measures is available for a few species (e.g., English sole) but little data for most groundfish. Little information on disease/parasite loads for groundfish stocks and little information on correlation with survival, growth, or reproduction.
   3. Areas of Improvement
      a. Develop more sensitive indicators of fish fitness and incorporate into monitoring plans.
      b. Incorporate data collection on disease/parasite load into monitoring
      c. Incorporate monitoring of contaminant concentrations in tissues/environment, especially for those species that use nearshore sites as part of their critical habitat.
      d. Conduct exploratory research to better understand the role of chemical contaminants in degrading habitat resources critical to survival and productivity of fisheries (e.g., depletion or reduced quality of prey base due to contaminants; avoidance of contaminated habitat).
      e. Conduct exploratory research to better understand how land-use practices and related activities (e.g., destruction of nursery areas, shoreline hardening, dredging practices) affect survival and productivity of fisheries.

D. Genetic diversity
   1. Objective - Reduce the threat of human activities on the genetic traits of a species. Each species has evolved to have traits that are well suited to its environment. In most cases, a species harbors sufficient genetic variability to allow it to adapt to changing environmental conditions. In addition, a species often is not freely mixed throughout its range, so that populations in particular areas may differ genetically from populations in other areas. Human activities, particularly fisheries, can upset this balance by imposing "unnatural" predators (fishermen) that are skilled at selecting large (i.e., fast-growing) individuals of a species and skilled at concentrating that mortality on fish tending to aggregate. Further, the overall geographic distribution of human activities and fishing can concentrate impacts on particular sub-populations.
   2. Current program
      a. Stock structure has been at least partially described for some species using tagging studies, and morphometric and genetic stock identification methods.
   3. Areas for Improvement
      a. Identify stock structure of each species, including description of partially isolated meta-populations and estimating genetically effective population sizes.
      b. Identify risks to species' genetic composition created by localized impacts to essential fish habitat, including spatially concentrated fisheries.
      c. Identify heritable traits that are at risk from anthropogenic impacts, including size-

selective fisheries.

IV. Ecosystem and climate studies

Goal - Determine whether the long-term health of the marine ecosystem is being sustained. The status of the ecosystem is susceptible to fluctuations caused by natural fluctuations in the ocean climate and by human influences. Some of these changes are direct, such as the impact of habitat degradation on productivity of particular species, or the impact of fisheries in reducing the average abundance of targeted species. Other changes are indirect and are caused by the predator-prey and competitory interactions between species; therefore they will be much more difficult to predict. Climate studies will improve stock assessment accuracy by distinguishing historical fishing from natural causes in fish abundance; improve short-term forecasts of fishery potential yield by developing more timely estimates of fish recruitment; improve projections of time scales for fish stock rebuilding by taking into account decadal scale cycles in productivity; and improve resource survey and fishery efficiency by predicting changes in fish abundance.

A. Ecosystem studies
    1. Extend monitoring programs in habitats essential to groundfish to detect changes in biodiversity and ecosystem function.
    2. Develop simple ecosystem scale food web models so that effects of fishery-induced changes in fish abundance can be more fully understood and predicted.
    3. Improve understanding of major predator-prey, and competitory interactions among species so that food web models can be improved.
    4. Understand feeding ecology of indicator species, how it is affected by environmental factors, and resulting impacts on growth, maturation, and fitness.
    5. Understand major host-parasite relations and disease prevalence in groundfish species so their influence on survival and productivity can be better quantified.
    6. Understand the linkage between habitat alteration/destruction and fisheries productivity so effects of anthropogenic activities can be more fully understood and predicted.

B. Ocean climate studies
    1. Current programs
        a. Ongoing ocean environmental monitoring.
            (1) Various NOAA, NASA, military agencies, including surface observations from ships of opportunity, collect oceanographic and meterological data. Coverage is not good in many areas and in subsurface waters. The NMFS Pacific Fishery Environmental Laboratory (PFEL) in Monterey assembles and analyzes much of this data with an explicit focus on fishery analysis.
            (2) largest program directed towards fishery-oceanography understanding is the 50-year-old CalCOFI program that now works only south of Morro Bay.
        b. Ongoing monitoring of fish recruitment
            (1) Stock assessments that include age-structured data usually provide a 20-30 year time series of recruitment.
            (2) Directed field program to measure recruitment of some rockfish species on an ongoing basis occurs only off central California.
        c. Fishery-oceanography investigations
            (1) NMFS West Coast programs studying the direct effect of ocean conditions on the physiology and survival of marine fish larvae and subsequent recruitment include: SWFSC-LaJolla program focusing on recruiting coastal pelagic species; NWFSC new program focusing largely on juvenile salmonids; the

SWFSC-Tiburon program focusing on rockfishes.

(2) Correlation studies of time series of fish recruitment and time series of oceanographic data indicate some evidence for similar patterns for several species. For some species, there is evidence for reduced recruitment in El nino years, high recruitment immediately after an El nino, and reduced average recruitment since the climate regime shift in 1977.

2. Areas of Improvement
   a. Monitor recruitment of more fish species to improve forecasting from stock assessments and to improve the understanding of the linkage between recruitment and ocean conditions.
   b. Monitor the ocean climate to improve predictions in fish distribution, recruitment and productivity.
   c. Develop understanding of the actual mechanisms by which the ocean climate affects fish recruitment, including predator distribution, prey availability, adverse transport patterns. Recent increases in the GLOBEC and PNCER programs will provide increased opportunities in this area.

C. Essential fish habitat (EFH)
   1. Objective - Identify habitat essential to the productivity of groundfish.
   2. Current program
      a. Develop maps of geographic distribution for each life stage of each species.
      b. Describe habitat.
      c. Develop guidelines and process for consultation regarding potential impacts on EFH.
   3. Areas of Improvement
      a. Improve understanding of fish assemblages and their association with particular habitats through examination of fishery and survey data, and dedicated studies using advanced imaging technologies. This has strong links to survey and life history program.
      b. Improve understanding of how conditions in each habitat influence fish productivity. What are the population level consequences of habitat alterations?
      c. Improve understanding of linkages between habitats and life stages. In particular, which habitat areas are sources of most successful reproductive output.

D. Marine reserves
   1. Objective - Safeguard the marine environment and harvested species against excessive anthropogenic impact, and provide increased human benefits through access to areas that have minimal impact from fisheries and other activities. These benefits include non-consumptive uses and recreational fisheries for trophy-sized fish. The impacts that are reduced by marine reserves include: overfishing due to inadequate knowledge of optimum harvest levels; changes in marine habitat and biota caused by fishing gear impacts; risks to fish stocks caused by reducing old age groups in optimally fished populations; possible changes in the average growth rate of fished species due to the increased fishing mortality on fish that grow faster and enter the fishery at an earlier age; and possible changes in the schooling tendency of some species because of the

fisheries' ability to target on fish aggregations.

2. Current program
   a. Modeling studies are being conducted to determine the effect of reserve size and location on the potential benefits, including evaluation of the effect of fish dispersal on the effectiveness of the reserve.
   b. Some small scale reserves have been implemented off California and in Puget Sound.
3. Areas of Improvement
   a. Establishing well-monitored research reserves to test potential effectiveness of larger scale implementation.
   b. Increased knowledge of fish mixing rates (from tagging studies, parasites, genetics, etc.) and location of productive source sites are needed to estimate biological effectiveness of various marine reserve sizes and siting schemes. Socioeconomic studies are needed to determine impacts of marine reserve siting and to develop effective means for community acceptance and enforcement.

V. Technological Innovation

Goal - develop technologies and knowledge to obtain the maximum benefits for fishing communities and the nation, and for cost-effective investigation and monitoring of this fishery and the affected stocks and ecosystem.

A. Utilization
   1. Objective - Develop new technologies for fuller and more valuable utilization of fishery products, and develop alternatives to conventional harvest.
   2. Current Program -
      a. Develop processing technologies for fuller utilization of fish processing waste.
      b. Develop technologies for production of more valuable fish products from currently harvested species and under-utilized species.
   3. Areas of Improvement
      a. Continue to advance the technology for fuller utilization of fish processing waste, undersized fish, and currently undesirable species.

B. Fish Culture and Enhancement
   1. Objective - develop technologies for environmentally safe and valuable aquaculture, develop fish culture technologies for enhancing depleted wild stocks, develop fuller understanding of the life history characteristics (e.g. feeding, growth, maturation, behavior) of target species.
   2. Current Program
      a. Create captive broodstock for target species. Sablefish, lingcod, and several rockfish are among the species under investigation.
      b. Develop understanding of each species requirements for feeding, growth, maturation, behavior.
   3. Areas of Improvement
      a. Continue studies to improve rearing technology.
      b. Conduct studies of the potential ecological effects of marine aquaculture.
      c. Conduct studies of the potential ecological and genetic effects of marine enhancement programs.
      d. Conduct bio-economic studies of the potential benefits of enhancement programs.

C. Research and monitoring tools
   1. Objective - develop new methods for cost effective investigation and monitoring of the fishery and the affected stocks and ecosystem.
   2. Current Program -
      a. Development and prototyping of electronic fish catch logbook.
      b. Development of new egg and larvae based surveys.
      c. Development of new trawl survey gear monitoring tools such as bottom contact sensors.
   3. Areas of Improvement (examples only)
      a. Development of advanced imaging technologies to augment and calibrate conventional surveys and investigate fish-habitat associations.
      b. Develop advanced fish tagging methods to improve study of movement patterns and abundance estimation.

VI. Management Support

The status of stocks, anthropogenic stress, and socioeconomic research areas provide a decision support system for sustainable fisheries. They provide an empirical approach to describing *what* are potential biological, social, and economic consequences of proposed management actions on fishery resources, their habitat, and fishery. The focus is on research and monitoring with the goal of providing the best available scientific advice for management decisions, with associated uncertainty, on a timely basis. A full management support system needs to look to the future also and develop technologies and knowledge that will enable consideration of new management alternatives.

A. Current Program
   1. Stock assessments and recommendations on annual quotas.
   2. Rebuilding plans.
   3. Consultations on essential fish habitat impacts, socioeconomic impact of fishery direct allocations, gear limitations, seasons, catch quotas, and individual limits, etc.
   4. Biological impacts of fishing gear regulations and bycatch reduction measures.
   5. Impacts of gear group allocations on the geographic distribution of catch.

B. Areas of Improvement
   1. Build standardized framework for community assessments and associated recommendations/uncertainty to fishery managers and constituents.
   2. Build a decision-support model for inseason management changes in trip limits.
   3. Improve biological, social, and economic analyses used in current program.
   4. Develop and evaluate alternative approaches to managing groundfish fisheries, rebuilding depleted groundfish resources, and protecting the marine ecosystem.